

ENAE 791 PROBLEM SET 1 – SPRING, 2012

DUE 3/1/12

Revised 2/26/12

- (1) You are launching a satellite into an initial parking orbit with a period of three hours and a perigee altitude of 350 km. You want to do a bitangent (Hohmann-type) transfer into a final elliptical orbit with a period of 12 hours and apogee at geostationary orbit ($r=42,240$ km). The orbits are coplanar and their major axes are colinear. Calculate the required Δv 's for the four possible transfers:
- (a) perigee(parking orbit) \Rightarrow perigee(final orbit)
 - (b) perigee(parking orbit) \Rightarrow apogee(final orbit)
 - (c) apogee(parking orbit) \Rightarrow perigee(final orbit)
 - (d) apogee(parking orbit) \Rightarrow apogee(final orbit)
- Which approach would you choose to minimize Δv ?

- (2) You would like to perform a deorbit maneuver from the final orbit in (1) to create a new perigee such that you enter Earth's atmosphere at an entry altitude of 125 km and a flight path angle of -2.5° . You could in general choose to perform this deorbit maneuver from any point on your orbit, but we'll keep it simple and consider only the apsides for now. Calculate the Δv and time from deorbit burn to atmospheric entry for descent from
- (a) apogee
 - (b) perigee
- (3) We are going to "reverse engineer" the Delta IV launch vehicle. Some critical parameters:

Common Booster Core (CBC):

m_{prop} : 199.6 MT

m_{gross} : 226.4 MT

I_{sp} : 365 sec

Second stage:

m_{prop} : 27.2 MT

m_{gross} : 30.7 MT

I_{sp} : 462.4 sec

Payload to ISS orbit: 23.25 MT

The following questions pertain to the Delta 4 baseline vehicle, which uses one CBC as the first stage.

- (a) What is the vehicle gross mass?
- (b) Calculate the Δv 's for the first and second stages
- (c) Calculate the trade-off ratios for each stage
 - (i) Effect of inert mass change on payload
 - (ii) Effect of marginal propellant mass on payload
 - (iii) Effect of additional exhaust velocity on payload

- (d) The Delta IV Heavy adds two additional CBCs to the center one. Assume the two "strap-on" CBCs are the first stage, the central CBC is the second stage, and the previous "second stage" is now the third stage. What payload can this carry to orbit (delta-V=9200 m/sec)?
- (e) The Delta IV Heavy actually lifts off with all three CBC engines running at 102% of rated thrust. At T+50 seconds, the center engine throttles back to 59%. At 235 seconds, the two outboard engines are throttled back to 57%. At 240 seconds, the outboard CBCs are jettisoned and the center engine throttles up to 102% thrust. It is throttled back to 57% at T+303 sec, and shut down at T+336 seconds. What payload can the Delta IV Heavy carry to orbit with this operating profile? How does it compare to (d)?